Running head: Processing resources and DRM false memories

Variations in processing resources and resistance to false memories in younger and older adults.

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ABSTRACT

The influence of available processing resources on the resistance to false memories (FMs) for lists of semantically related items associated with a non-presented critical lure was examined in younger and older adults. Reducing the available resources at encoding in younger adults (Experiment 1 and 2) led to a performance similar to the older adults' one (i.e., higher rates of FMs in addition to reduced rates of correct recall). However, increasing the available resources (Experiment 2 and 3) yielded to improvements in the rates of correct recall in both age groups and decreased the probability of FMs in younger adults although warnings had to be added in older adults to obtain similar effects on FMs. Parallel influences on a post-recall test asking participants to report items that they had thought of but did not recall were also found. The influence of available cognitive resources for memory accuracy is also discussed with respect to activation-monitoring (e.g., McDermott & Watson, 2001) and fuzzy-trace (e.g., Brainerd & Reyna, 2002) accounts of age-related increased in false memories.

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Introduction

A growing amount of data indicates that normal aging influences memory accuracy (e.g., Zacks, Hasher, & Li, 2000). In addition to a breakdown in veridical memory performance, aging is associated with increased susceptibility to various kinds of false memories (e.g., Koutstaal & Schacter, 2001; Schacter, Koutstaal, & Norman, 1997) and deficits in source monitoring (Johnson, Hashtroudi, & Lindsay, 1993; see Spencer & Raz, 1995, for a meta-analysis), a set of processes involved in resistance to false memories (e.g., Brédart, 2000; Dehon & Brédart, 2004; Johnson & Raye, 2000). The aim of the current experiments was to gain a better understanding of age-related deficits in source monitoring abilities, and the role of source monitoring in resistance to false memories.

The DRM Paradigm was used (Deese, 1959; Roediger & McDermott, 1995) in three experiments. For this procedure, multiple thematic lists of words are presented during a study phase. Each list is composed of many words, all of which are related to a critical non-presented word lure, referred to as the critical lure (e.g., *thread, pin, eye, sewing, sharp,* etc., for which the non- presented critical lure is NEEDLE). This paradigm has proved useful for studying memory errors, because it elicits robust levels of false recognition and recall of the critical lures (see Roediger, McDermott, & Robinson, 1998, for a review). In addition to the robust false memory effect, participants who make these errors do not say simply that the critical lure seems familiar to them, but that they actually remember very specific aspects of its presentation at study (Roediger et al., 1998).

Two common theoretical accounts of the DRM false memory effect are derived from fuzzy-trace theory (e.g., Brainerd & Reyna, 2002; Brainerd, Wright, Reyna, & Mojardin, 2001) and activation monitoring theory (e.g., Gallo & Roediger, 2002; McDermott & Watson, 2001; Roediger, Watson, McDermott, & Gallo, 2001). According to the fuzzy-trace theory account, memory judgements are based on verbatim or gist traces that are encoded in parallel at study. Verbatim traces capture the surface details of physical stimuli and gist traces represent the meaning of the stimuli but lack perceptual details. Recall of studied items is based on a dual retrieval mechanism. One mechanism involves direct access to verbatim traces of list items and mainly supports veridical recall. A second mechanism reconstructs the items by processing the gist representation. This later mechanism sometimes supports true recall and is responsible for false recall (e.g., Brainerd & Reyna, 2002; Brainerd et al., 2001). More specifically, critical lures are identified as part of the presented lists due to the attributes they share in common with the items on their corresponding study list. Verbatim representations can also be used to edit out critical lure items during recall. Indeed, false-but-cue-consistent information may come to mind during recall and cue verbatim details of the corresponding presented items, which may counter the familiarity associated with false-but-cue-consistent information (e.g., Brainerd et al., 2001).

According to the activation-monitoring account (e.g., McDermott & Watson, 2001), false memories occur because during the presentation of the associated words in the list, the critical lure is activated. This activation may occur either consciously following elaborative processing (e.g., Brédart, 2000; Gallo, Roberts, & Seamon, 1997; Goodwin, Meissner, & Ericsson, 2001; Kensinger & Schacter, 1999; McDermott & Watson, 2001), or automatically as a result of spreading activation in an associative network (e.g., McDermott & Watson, 2001; Seamon, Luo, & Gallo, 1998). Whatever the exact nature of its activation, when a critical lure has been activated, it must be correctly attributed during retrieval to the participant's own thoughts and not to the item's occurrence in the list through a successful reality monitoring process (Johnson et al., 1993; Johnson & Raye, 2000).

Both accounts imply that the critical lure will be likely to seem familiar to both younger and older adults due to either activation or reliance on gist traces. These feelings of familiarity may be particularly difficult for older adults to resist (e.g., Balota et al., 1999; Dehon & Brédart, 2004). According to the activation-monitoring account, critical lures experienced as being highly familiar will be more difficult for older adults to correctly reject, because of age-related deficits in (source) monitoring processes. By the fuzzy-trace theory account, critical lures will likely be falsely recalled or recognised by older adults because of their decreased ability to encode well-integrated verbatim traces for list items. Although both theories rely on an editing mechanism that discriminates between highly familiar/activated items and actually experienced items on the basis of available item-specific information, they diverge on whether false recall of critical lures is a misrecollection of events occurring during the study episode or an experience constructed during retrieval. Indeed, according to the activation-monitoring account, critical lures are activated during the presentation of the lists to the point of being experienced as having been produced at that time. In contrast, the fuzzy-trace account suggests that the activation of the critical lure at the study phase is not a necessary condition for false memories to occur. Rather, critical lures seem familiar, because they are consistent with the gist of their corresponding lists.

Recently, Dehon and Brédart (2004) examined younger and older participants' performance using a modified memory procedure (Brédart, 2000) designed to more directly assess activation and monitoring processes in the DRM paradigm. More specifically, the modified procedure allowed participants to indicate whether they were aware of having consciously activated critical lures. In these experiments, participants studied French DRM lists and completed a free recall test after each list. After completing all the recall memory tests, participants were asked to indicate if, during the learning phase or during the recall phase, a word came to mind but they did not write it down during the recall task, because they thought the experimenter had not uttered it. The experimenter then presented the participants with the word lists they recalled during the recall phase, one after another, and asked them to write down any other words they had thought of when recalling the words for that list. This modification allowed for the investigation of the extent to which a reality monitoring process was used to avoid falsely recalling critical lures. By the activation-monitoring account, a failure to recall a critical lure either in the initial recall phase or during the additional phase suggests that the list failed to activate it. On the other hand, the reporting of a critical lure during the added phase, but not during the initial recall test, is indicative of successful monitoring.

Older adults recalled fewer studied items and more critical lures than younger adults during the initial recall test. Elderly adults were also less likely to recall the critical lure during the additional phase than younger adults. However, younger and older adults were just as likely to activate the critical lures. That is, the summed proportions of critical lures recalled at test and critical lures produced during the additional phase were equal in young and older adults. The critical difference was that the number of false recalls was greater in older adults and the number of critical lures produced during the additional phase was higher in younger adults. Moreover, this result persisted even when older adults were strongly encouraged to examine the origin of their memories (Dehon & Brédart, 2004, experiment 2).

Overall, the main finding of these two experiments was the observation that younger and older adults are aware of consciously activating the critical lure, which is in accordance with the activation-monitoring account. In addition, both groups were just as likely to think of the critical lures. Older adults preferentially recalled them during the initial recall test, while younger adults recalled them during the additional phase. These results are important because they highlight the source monitoring deficit experienced by older adults that allows for the occurrence of false memories in the DRM paradigm.

Overview of present experiments

Earlier research suggests that younger adults may be better at activation monitoring than older adults, but does not specify the causal mechanisms involved. According to the Source Monitoring Framework (e.g., Johnson et al., 1993; Johnson & Raye, 2000), there may be several explanations of older adults' deficits in source monitoring efficiency. Indeed, source monitoring processes rely on phenomenal and distinctive information that accompanies memories (see for example, Johnson & Raye, 2000). For instance, older adults' susceptibility to false memories and deficits in source monitoring efficiency might be due to age-related difficulties in accessing distinctive information during retrieval and/or in encoding information less distinctively (Schacter et al., 1997). Overall, the data suggest that older adults are more likely to rely upon relational processing during both encoding and retrieval, because they lack the attentional resources necessary to focus on both relational information (i.e., indistinct, thematic information) and item-specific information (e.g., Anderson & Craik, 2000; Craik, 1982). Hence, three experiments were performed to investigate the relative impact of encoding deficits in comparison to retrieval and evaluation deficits on age-related differences in source monitoring accuracy.

In experiment 1, attentional resources were manipulated by dividing younger participants' attention at study, at test, or at both study and test, and these conditions were compared to a group of older adults in the full attention condition. It was hypothesised that dividing younger participants' attention at the time of study would limit their ability to encode item-specific information, while dividing their attention at the testing time would reduce their ability to effectively query item-specific information. The lack of item-specific information should impair the functioning of monitoring processes (e.g., Johnson et al., 1993; Johnson & Raye, 2000) and lead to higher rates of false memories. Finally, dividing attention at both study and test may have an over-additive effect. Consequently, the performance of younger adults in this condition might approximate that of older adults.

Given its implication in age-related deficits in cognitive performance (e.g., Anderson & Craik, 2000; Clarys, Isingrini, & Gana, 2002; Salthouse, 1996), the influence of speed of processing on memory accuracy was also examined in younger and older adults. In experiment 2, three Inter-Stimuli Interval (ISI) lengths (i.e., 0.5 s, 1.5 s and 3 s) were used in separate groups of younger adults, and in experiment 3, ISI was manipulated only for older adults. A longer ISI was expected to allow for more effective processing of item-specific information, which could subsequently be used to reduce false recall of critical lures. In contrast, a shorter ISI would preclude the encoding of item-specific information and make memory editing more difficult. However, because older people sometimes fail to spontaneously use strategies that could help them to avoid memory errors (Koutstaal, Schacter, Gallucio, & Stofer, 1999; Multhaup, 1995; Watson, McDermott, & Balota, 2004), the spontaneous use of source monitoring processes could account for older adults' pattern of performance. Hence, in experiment 3, in addition to the use of a longer ISI, a separate group of older adults was given strict warnings before the study phase, in an attempt to make them engage monitoring processes.

Experiment 1

The aim of the first experiment was to identify the relative contributions of encoding quality and retrieval processes to false memory resistance. A dual task methodology was used in the modified procedure to investigate the impact of limited processing resources during encoding and/or retrieval on the resistance to false recall in the DRM paradigm.

The dual task methodology has typically been used to examine the costs of limited processing resources on general measures of memory (i.e., recall and/or recognition) and studies have shown that a concurrent task performed at study impairs later memory performance, although the same task applied during retrieval has a relatively weaker effect (see Craik, 1999, for a review). However, some studies have demonstrated that an additional concurrent task imposed during study (e.g., Jacoby, Woloshyn, & Kelley, 1989; Jennings & Jacoby, 1993; Perez-Mata, Read, & Diges, 2002) or retrieval (e.g., Jacoby et al., 1989) to usually increase the rates of false memories. For example, Jennings and Jacoby (1993) found dividing attention at study to increase false fame errors. However, to our knowledge, only a few studies have examined the impact of dividing attention on the occurrence of false memories in the DRM paradigm (Payne, Lampinen, & Cordero, 1996, cited in Roediger et al., 1998; Perez-Mata et al., 2002; Seamon et al., 1998, 2003). These studies only manipulated divided attention at study and their results were mixed. For instance, the Payne et al. 's (1996) study presented participants with words visually while they simultaneously listened to random series of numbers and pressed a specific key when three odd numbers occurred sequentially in one series. Using this procedure, they found that dividing attention decreased both true and false recognition performance (see also Seamon et al., 1998). In contrast, Perez-Mata et al. (2002), using another monitoring task, observed dividing attention to decrease true recall but to increase false recall.

Because these studies varied greatly in their procedural details, it is very likely that their divergent results might be due to the levels of list learning they afforded (see Seamon et al., 2003). Indeed, McDermott and Watson (2001) manipulated the range of presentation rates (from 20 ms to 5000 ms) of the material under full attention conditions (i.e., without any concurrent task). They showed that accurate and false memories were differentially influenced by the level of list learning. That is, they observed that increasing the time from 20 ms to 1000 ms increased both true and false recall. In contrast, they observed that increasing presentation times from 1000 ms to 5000 ms reduced false recall and increased true recall. In other words, as presentation times increase, so does the associative activation that underlies both true and false memory performance. However, with slower rates of presentation, participants are able to extract additional specific information and detect differences between actually presented and activated items. It is very likely that, in the Payne et al.'s (1996) study, the concurrent task was highly resource-demanding and affected the activation processes underlying both true and false memory performance in a way similar to the speeded presentation of study items. Conversely, in Perez-Mata et al.'s (2002) study, the concurrent task may have been less resource-demanding and reduced the likelihood of encoding item-specific information for studied items (i.e., perceptual, contextual details) and critical lures (i.e., perceptual and cognitive activities), rather than reducing the activation of semantic associates.

As outlined above, the Source Monitoring Framework (see Johnson et al., 1993; Johnson & Raye, 2000) suggests several loci of influence that might be responsible for the higher rates of memory distortions in older adults. Indeed, in addition to indistinct encoding, the use of lenient criteria and/or failure to access distinctive information during retrieval are some of the various factors involved in memory distortions. Hence, because the source monitoring processes operate on the basis of phenomenal and item-specific information, any condition that affected the availability of such information would impair source monitoring efficacy (e.g., Johnson et al., 1993). Consequently, the relative contributions of encoding *and* retrieval deficits to age-related differences in source monitoring accuracy should be investigated. Finally, older participants have not been included in previous research using a dual task methodology in the DRM paradigm. As such, it has not been possible to more directly test the hypothesis that a limited quantity of processing resources either during encoding and/or during retrieval is responsible for the memory deficits attributed to normal aging.

For all these reasons, attentional resources were manipulated by dividing younger participants' attention at study, at test, or at both study and test, and these conditions were compared to a group of older adults paying full attention. In addition, activation and monitoring processes were observed more directly using Brédart's (2000) modified procedure. It was hypothesised that dividing attention at study would reduce the successful extraction of item-specific information which would results in both reduced rates of true recall and increased rates of false recall. In line with the previous literature (see Craik, 1999, for a review), the addition of a concurrent task at test was not expected to affect true recall during the initial recall test. However, a dual task at test should reduce younger participants' ability to effectively query item-specific information. The lack of item-specific information would, in turn, affect the accurate functioning of the editing processes (e.g., through a greater reliance on relational information), which would lead to increased rates of false memories. Finally, the combination of these two manipulations may be over-additive and may mimic the pattern of performance observed in normal aging. In contrast, dividing attention was not expected to influence the activation of the critical lure, because automatic activation of the critical lure does not depend upon selective attention. Therefore, the summed proportions of critical lures recalled at test and critical lures produced during the additional phase should be equivalent in all groups, whereas false recall should be greater in older adults and in young adults with a dual task at study and/or retrieval compared to younger adults in the full attention condition.

Method

Participants. Ninety-six young college students (46 females and 50 males; mean age = 20.85 ± 1.93, ranging from 18 to 25) participated in the experiment. They were tested individually, and were randomly assigned to one of six conditions: 'full attention' (later referred to as 'FAyoung'), 'dual task during encoding' ('DAe'), 'dual task during retrieval' ('DAr'), 'dual task during both encoding and retrieval' ('DAer'), 'full attention with oral response' ('FAor'). Twenty older adults (10 females and 10 males, 70.60 ± 7.34, ranging from 59 to 82) also participated to the experiment, and were tested in the full attention condition (later referred to as 'FAold'). All participants were in good health and reported no history of alcohol or drug abuse, cerebrovascular aetiology, myocardial infarction, psychiatric treatment or psychotropic medication, or head injury (descriptive data are given in table 1). Participants were also selected according to educational background, and had at least 11 years of education. Table 1 also shows that, on average, the participants in the 'DAr' condition (see description in the procedure section) had significantly more years of education than the older adults, although there were no significant differences between the participants in these two conditions and younger participants in the other experimental conditions, $F(5,110) = 3.15$, $MSE = 2.90$. However, on average, the older adults had significantly higher scores on the Mill Hill Vocabulary Test than the younger participants, $F(5,110) = 4.40$, $MSE = 9.93$.

Please insert table 1 about here

Materials. Participants were presented with six French DRM word lists of 15 items each (for a detailed presentation of the material, see Dehon & Brédart, 2004). A female voice uttering the words was recorded and digitalised. Lists were presented in random order using a computer. The interval between items was 1.5 s and the durations of the recorded lists ranged from 34 to 37 s.

Procedure. The same general procedure was applied to all groups of participants. The participants were tested individually, and were seated in front of a computer. They were told that they would hear six lists of words, and would be tested for each list after counting backward by threes for 30 seconds. The six lists were presented in random order for each participant and memory was tested after each list. For each recall phase (Phase 1), the participants were instructed to recall as many words as possible from the list they had just heard. They were then asked to write down the words in any order on a sheet of paper, without guessing. They were given 90 seconds to complete each recall phase. After completing recall tests for each of the six lists, the first post-recall task was administered. For this task (Phase 2), participants rated their confidence about having heard a word in the list they had just heard on a 5-point scale (1 = not very confident, 3 = fairly confident, 5 = extremely confident that the experimenter had presented the word).

In a second post-recall phase (Phase 3), participants indicated whether, during the learning or recall phases, a word had come to mind but they had not written it in the recall test. The participants were presented with the six word lists in succession. They were asked to write down, using a different-coloured pen, any other words that they had thought of when the lists were originally presented, but that they had not reported on the recall task because they knew the experimenter had not presented it. Participants were instructed to write down only words they remembered having thought of during the presentation of the lists, and not to infer or guess words. During the final phase, participants assigned a rating of 1 to 5 (1 = not very confident, 3 = fairly confident, 5 = extremely confident that the experimenter did not present the word) to each of the words they had generated, reflecting their confidence about *not* having heard it at study. The participants also completed a French-language adaptation of the Mill Hill Vocabulary Scale at the end of the testing. Finally, the participants were fully debriefed.

The participants in the conditions involving a dual task during study and/or retrieval (i.e., study only, retrieval only, study and retrieval) were also instructed about the presence and nature of the digit monitoring task. They were told that they would be asked to perform a concurrent task only during study, only during retrieval, or during both study and test. For this task, single digits were presented one at a time on the computer screen in a pseudo-random order. Participants were instructed to press the space bar when three identical digits appeared sequentially. The length of the dual task matched either the length of the lists to be remembered in the conditions involving a dual task during study (from 34 to 37 s) or the recall duration in the conditions involving a dual task at retrieval (i.e., 90 s).

A sixth condition (i.e., full attention but oral response 'FAor') was included in order to control for a methodological modification involved whenever the dual task appeared during retrieval (i.e., 'DAr' and 'DAer' conditions). In the standard condition, the material to be remembered was presented auditorily and participants wrote down their recall responses. However, the dual task required participants to monitor digits presented visually on a computer screen, precluding them from writing down their responses. Therefore, in conditions involving the dual task at retrieval, the experimenter wrote down the words recalled by the participants. In order to be sure that this manipulation was not totally or partially responsible for the observed effects in the DAr and DAer conditions, an additional group (n = 16) followed the same general procedure except that they responded orally during the memory test while the experimenter noted their responses.

Results and discussion

The descriptive data as a function of the experimental condition are presented in table 2. For all the following analyses, the alpha level was set at .05.

Please insert table 2 about here

Performance in recall (Phase 1).

The proportions of non-critical intrusions, mainly semantically related intrusions, were not statistically affected by the available attentional resources, $F(5,110) = 1.41$, $MSE = 0.01$, $p = .23$. Because those proportions were very low (≤ .03), they did not undergo additional statistical analyses.

A 6 (Condition: ‘FAyoung’ vs. ‘DAe’ vs. ‘DAr’ vs. ‘DAer’ vs. ‘FAor’ vs. ‘FAold’) X 2 (Item Type: ‘studied item’ vs. ‘critical lure’) ANOVA with repeated measures on the last factor was performed on the mean proportions of true and false recall (see table 2). This analysis revealed no significant main effect of the Condition, $F(5,110) = 1.81$, $MSE = 0.02$. A significant effect for Item Type was obtained, $F(5,110) = 66.18$, $MSE = 0.04$ showing that the mean proportion of true recall (.54 $\pm$ .08) was higher than the proportion of false recall (.32 $\pm$ .23). However, the Condition X Item Type interaction was also significant, $F(5,110) = 9.49$, $MSE = 0.03$. Planned comparisons showed that young adults in full attention, young adults in full attention but responding orally, and young adults with dual task demands at testing recalled significantly more studied items than participants in any other condition. The older adult participants recalled significantly fewer studied items than any other condition including, contrary to our predictions, younger adults whose attention was divided only at study and younger adults whose attention was divided at both study and test. This suggests that, while including a concurrent task only during encoding or during both encoding and retrieval impaired the recall of test items, this manipulation was not sufficient to perfectly match younger and older participants with respect to correct recall.

With respect to false recall, ‘FAyoung’ and ‘FAor’ participants recalled significantly fewer critical lures than participants in any other condition. The rates of false recall in the conditions involving dual task at study and/or at retrieval were similar. In addition, these rates did not differ statistically from the rates of false recall obtained by the ‘FAold’ participants. This suggests that, even if the manipulation of available attentional resources was not sufficient to perfectly match younger and older adults on correct recall, it did, in agreement with the Source Monitoring Framework predictions, match them for false recall. Finally, the rates of true memories were significantly higher than the rates of false recall in the ‘FAyoung’, ‘FAor’ and ‘DAr’ conditions but were similar in the remaining conditions (i.e., ‘DAe’, ‘DAer’ and ‘FAold’ conditions).

The same analysis was conducted on the confidence ratings assigned to true and false memories (see table 3). This analysis revealed a significant main effect for Condition $F(5,94) = 1.98$, $MSE = 0.08$. HSD Tukey post hoc tests showed that, overall, the confidence ratings were statistically higher in older participants than in ‘FAyoung’, ‘FAor’ and ‘DAr’ participants while they were similar in the other groups. A significant effect of Item Type was obtained, $F(1,94) = 73.58$, $MSE = 0.65$. Confidence ratings assigned to true items (4.66 ± 0.48) were higher than the confidence ratings assigned to the critical lures (3.67 ± 1.29). Finally, the Condition X Item Type interaction was also statistically significant, $F(5,94) = 2.54$, $MSE = 0.65$. Planned comparisons revealed that all of the younger groups assigned significantly higher confidence ratings to studied items than to critical lures. Older adults, on the other hand, assigned equivalent confidence ratings to studied items and critical lures.

Please insert table 3 about here

Recall during the additional phase (Phase 3) and confidence. The proportion of critical lures recalled during the additional phase was computed for the participants in each of the groups (see table 2). A one-way ANOVA was carried out on these mean proportions and revealed a significant main effect of the Condition, $F(5,110) = 5.13$, $MSE = 0.09$. As expected, younger participants whose attention was not divided and younger participants whose attention was only divided at test listed significantly more critical lures during the additional phase than any other condition. The proportions of critical lures produced during the additional phase were similar in the remaining conditions.

In the previous analyses, predictions regarding the distribution of the critical lures in the different phases of the experiment (i.e., recall in phase 1 or in the additional phase) were tested. The next analyses specifically addressed the cases for which false memories did not occur during the initial recall phase. For each group, an index was computed by dividing the number of critical lures recalled during the additional phase by the number of critical lures that could still be recalled theoretically [i.e., the number of critical lures recalled during the additional phase / (the number of critical lures recalled during the additional phase + the number of critical lures that were never recalled)]. This results in a value ranging from 0 to 1. The index equals 0 if none of the critical lures that were not recalled in phase 1 are recalled in phase 3 (which means that these critical lures were not activated). Conversely, it equals 1 if all of the critical lures are recalled in phase 3 (meaning a successful monitoring of those lures). This index was computed for each participant in each group. A one-way ANOVA was computed on these indices and revealed a main effect for Condition, $F(5,110) = 2.85$, $MSE = 0.15$, that showed that the mean indices in the 'FAyoung' and 'FAor' groups (.72 $\pm$ .34 and .80 $\pm$ .26, respectively) were statistically higher than the indices from any other condition (.50 $\pm$ .45, .44 $\pm$ .41, .49 $\pm$ .43, and .46 $\pm$ .34 for the 'DAe', 'DAr', 'DAer' and 'FAold' groups, respectively).

Then, the index for each condition was compared to the theoretical proportion of 0.5 to determine whether the recall of the critical lure during the additional phase was at the chance level. A high index value that differs from the chance level indicates that monitoring is a good explanation for why false memories did not occur at some trials. In contrast, an index that is statistically not different from 0.5 shows some evidence of monitoring, even if at the chance level. The results showed that only the mean indices in the 'FA young' and the 'FAor' groups were statistically higher than the theoretical proportion of 0.5 [$t(19) = 3.98$ and 4.01, for the 'FA young' and the 'FAor', respectively]. The mean indices in the other groups did not differ statistically from the theoretical proportion of 0.5 [$t(19) < 1$ for all the remaining groups].

The proportions of activated critical lures (critical lures recalled during the memory test + critical lures produced during the additional phase) were also compared (see table 2). The effect of Condition was not statistically significant, $F < 1$. This finding is important because it suggests that the participants were equally likely to think of the critical lure in all the conditions, but manipulating the available attentional resources during study and/or retrieval is sufficient to affect memory accuracy (i.e., higher rates of false recall associated with lower rates of critical lures produced during the additional phase).

Finally, a one-way ANOVA carried out on the mean confidence ratings assigned to the critical lures produced during the additional phase (see table 3) showed no effect of Condition, *F*

< 1. This suggests that, although the ability to successfully monitor the origin of one's memories is strongly affected by normal aging and dual task demands at study and/or at test, these variables had no effect on the confidence associated with the successful monitoring of a critical lure.

In conclusion, in line with previous experiments, any condition that affected the availability of processing resources naturally (i.e., normal aging) or artificially at study (i.e., dual task demands at study, dual task demands at study and retrieval) decreased true recall (although a perfect match between the younger and older adults' performances was not achieved), whereas full attention or dual task demands at test did not affect correct performance. In contrast, any condition that affected the availability of processing resources naturally (i.e., normal aging) or artificially at study *or* at test (i.e., dual task demands at study and/or at test) was sufficient to substantially increase the proportion of false memories. Moreover, as predicted, the summed proportions of critical lures recalled at test and critical lures produced during the additional phase were similar in all groups, but the number of false recalls was greater in older adults and in young adults with a dual task at study and/or retrieval whereas the number of critical lures produced during the additional phase was higher in younger adults in the full attention condition. In accordance with the activation-monitoring account, these results suggest that all the participants were equally likely to think of the critical lure but that reducing the available attentional resources during study and/or retrieval was sufficient to affect memory accuracy (i.e., higher rates of false recall) through the efficiency of the source monitoring processes (as measured by the performance in the additional phase). In addition, the results also showed that oral response in itself had no effect given that the performance of this group was not different from the performance of the younger adults in the full attention condition. This suggests that the results obtained for the ‘DAr’ and ‘DAer’ groups cannot be attributable to a divergence in the methodology used for these two groups.

However, some limitations to our results must be considered. First, the addition of dual task demands at both study and test did not lead to an over-additive effect. It is possible that, in this condition, the expected negative effects of dual task demands were paradoxically opposed, because of a kind of ‘context reinstatement effect’ (see the ‘encoding specificity principle’, Tulving, 1983). That is, when performing the memory test and the concurrent task during the test phase, these participants might have been put into a context similar to that of the study phase. However, although this explanation is likely, this factor did not play a major role here, because the reinstatement of context usually improves true memory performance as well, which is not consistent with our results.

Second, the main finding of this study is that, in agreement with the Source Monitoring Framework, manipulating the available attentional resources during study and/or retrieval is sufficient to affect memory accuracy (i.e., higher rates of false recall). Because it is necessary to disturb the quality of encoding to obtain a pattern similar to the older adults’ pattern (i.e., higher rates of false recall in addition to reduced rates of true recall), this finding highlights the importance of the encoding stage in older adults’ resistance to false memories (see also Gallo, Roediger, & McDermott, 2001). However, a recent study showed that, instead of making item-specific information less available homogeneously, the use of a concurrent task at study in younger adults may impair their memory for both item and contextual information (Naveh-Benjamin, Guez, & Marom, 2003). Hence, the influence of available processing resources during study should be examined more specifically in a way that would allow: 1) each item to be equally likely to be perceived, and 2) the possibility of engaging in more distinctive processing of items to be manipulated. Processing speed could be a good candidate in this regard. Moreover, because this variable has been found to be one of the most important factors explaining the age-related variance in memory (Anderson & Craik, 2000; Clarys et al., 2002; Salthouse, 1996), its influence on memory accuracy should also be considered. To this end, the Inter-stimuli Interval (ISI) should be manipulated in order to either facilitate or decrease the probability of extracting item-specific information at study. In addition, relative to a dual task condition, the advantage of using shorter ISIs to examine the effect of limited processing resources on memory accuracy is that every item is similarly perceived but the time allowed to encode an item in a more elaborate fashion is manipulated. Thus, in the second experiment, the effect of processing speed was investigated in groups of young adults.

Experiment 2

One means of observing an effect of processing speed is to examine the influence of presentation duration on subsequent memory performance. Several previous experiments have included manipulations of presentation duration, but the results of these experiments were mixed (i.e., McDermott & Watson, 2001; Roediger et al., 1998). Some experiments demonstrated a reduction in false recall of critical lures (e.g., Gallo & Roediger, 2002), while others showed an increase in false recognition of critical lures (e.g., Seamon et al., 1998). These inconsistent results may be due to differences in presentation time used across these experiments. In an attempt to better understand the origins of the discrepant results, McDermott and Watson (2001) employed a wider range of presentation times (from 20 ms to 5000 ms). They observed that accurate recall increased monotonically over exposure durations whereas false recall showed an inverted U-shaped relation with increased exposure duration. That is, true and false recall both increased with rapid presentation rates. However, with slower rates of presentation (from 1000 to

5000 ms), participants were able to extract additional specific information to reduce false recall while improving their accurate recall. More recent research has also manipulated presentation duration in younger adults, but has provided inconsistent data. Indeed, McCabe and Smith (2002) presented the material at a rate of either 2 s or 4 s. They observed that this manipulation has no effect on younger adults' rates of hits or false alarms on a recognition memory test. Watson et al. (2004) used a different range of presentation rates (1.250 s versus 2.5 s) and found no effect of presentation duration when measuring false recall performance. These divergent results may be related to the range of presentation used, which would not have been optimal to reveal differences in younger adults, or to differences in methodology.

The aim of experiment 2 was to specify the impact of a particular processing resource (i.e., speed of processing) and its involvement in the observed effects of aging on the ability to monitor critical lures. Three ISI lengths (0.5 s, 1.5 s and 3 s) were used in separate groups of younger adults in the modified procedure. Although these manipulations follow the theoretical propositions of McDermott and Watson's (2001) work, a major divergence between their research and the present experiment is that presentation duration per se was not manipulated. Rather, it is the time allowed to engage in item-specific processing that was favoured or reduced. In addition, the modified recall procedure was used in order to allow for the successful activation and monitoring of critical lures to be more directly assessed.

Specifically, a longer ISI should allow for more effective processing of item-specific information, which could subsequently be used to decrease the false recall of critical lures. In contrast, a shorter ISI should reduce the likelihood of item-specific processing. Thus, young adults in the shorter ISI condition should recall fewer studied items and more critical lures during the initial recall than any other condition. Conversely, young adults in the longer ISI condition should recall more studied items and fewer critical lures than any other condition. However, because the ISI lengths used in this experiment should allow the critical lures to be sufficiently activated (McDermott & Watson, 2001), the rates of activated critical lures should not differ between the experimental groups. Therefore, the summed proportions of critical lures recalled at test and in the additional phase should be equivalent across all groups, but the number of critical lures falsely recalled on the initial recall test should be greatest in the shortest ISI condition. In contrast, the number of critical lures produced during the additional phase should be greatest for the participants in the longest study presentation condition.

Method

Participants. Forty-eight college students (28 females and 20 males, ranging from 18 to 26; mean age = 21.5 +- 2.5 years) participated in the experiment. They were randomly assigned to one of the three experimental conditions (later referred to as ‘shorter ISI’, ‘standard ISI’ and ‘longer ISI’). The three groups of participants were similar with respect to their age, $F(2,45) = 1.84$, $MSE = 11.23$, their education [14.42 $\pm$ 1.74, 13.8 $\pm$ 2.10, and 14.9 $\pm$ 1.89 years of education; $F(2,45) = 1.54$, $MSE = 9.37$], and their mean score on the Mill Hill Vocabulary Scale [37.45 $\pm$ 3.91, 36.69 $\pm$ 3.38, and 36.75 $\pm$ 2.65; $F(2,45) = 1.31$, $MSE = 8.85$].

Material. The same material as in experiment 1 was used except that following the experimental condition the ISI was manipulated. In the ‘shorter ISI’ condition, a 0.5 s ISI was used. The ISI length was 1.5 s in the ‘standard ISI’ condition and 3 s in the ‘longer ISI’ condition. The duration of the resulting lists ranged from 18 s to 22 s in the ‘short ISI’ condition, from 34 s to 37 s in the ‘standard ISI’ condition, and from 57.5 s to 58.5 s in the ‘longer ISI’ condition.

Procedure. The participants were tested individually and followed the same general procedure as in experiment 1. The only manipulation was the ISI length of the material to be remembered: 'shorter ISI' (ISI = 0.5 s), 'standard ISI' (ISI = 1.5 s) and 'longer ISI' (ISI = 3 s).

Results and discussion

The descriptive data as a function of the experimental condition are presented in table 4. For all the following analyses, the alpha level was set at .05.

Please insert table 4 about here

Performance in recall (Phase 1).

A one-way ANOVA performed on the proportions of non-critical intrusions, mainly semantically related intrusions, showed a main effect for Condition, [$F(2,45) = 3.07$, $MSE = 0.01$]. The proportions of non-critical intrusions were similar in 'shorter ISI' (0.02 $\pm$ 0.02) and 'standard ISI' (0.03 $\pm$ 0.02) participants, while 'longer ISI' participants (0.02 $\pm$ 0.01) recalled marginally lower rates of these intrusions ($p = .08$). As in experiment 1, further statistical analyses were not performed on the proportions of non-critical intrusions.

A 3 (Condition: 'shorter ISI' vs. 'standard ISI' vs. 'longer ISI') X 2 (Item Type: 'studied item' vs. 'critical lure') ANOVA with repeated measures on the last factor was performed on the mean proportions of true and false recall (see table 4). This analysis did not reveal a main effect for Condition, $F(2,45) = 0.62$, $MSE = 0.02$. However, a significant main effect for Item Type was obtained, $F(1,45) = 412.82$, $MSE = 0.01$. Participants recalled more studied items (.63 $\pm$ .06) than critical lures (.15 $\pm$ .18). In addition, the Condition X Item Type interaction was also significant, $F(1,45) = 41.24$, $MSE = 0.02$. Planned comparisons showed that, in comparison to the standard ISI, the shorter ISI led to fewer studied items being recalled, while lengthening the ISI led to more studied items being recalled, $F(1,45) = 35.39$, $p < .0001$; $F(1,45) = 88.16$, $p < .0001$.

As hypothesised, ‘longer ISI’ participants recalled significantly lower proportions of critical lures than ‘standard ISI’ and ‘shorter ISI’ participants, $F(1,45) = 7.92$, $p = 0.029$; $F(1,45) = 25.67$, $p = .007$. The proportion of false recall in the ‘shorter ISI’ condition was significantly higher than that observed in ‘standard ISI’ participants, $F(1,45) = 5.07$, $p < .0001$. This suggests that the indirect manipulation of processing speed (i.e., reducing or expanding the time available to distinctively encode information) influenced both true and false recall. However, the proportion of studied items recalled was larger than the proportion of critical lures recalled in the ‘shorter ISI’, ‘standard ISI’ and ‘longer ISI’ conditions, $F(1,45) = 32.73$, $p < .0001$; $F(1,45) = 120.39$, $p < .0001$; $F(1,45) = 342.18$, $p < .0001$.

The same overall analysis was performed on the confidence ratings assigned to true and false memories (see table 5). A significant Item Type effect was observed, $F(1,24) = 14.82$, $MSE = 0.92$. Overall, participants were more confident when recalling studied items (4.76 ± 0.21) than critical lures (3.47 ± 1.67). No effect of Condition ($F < 1$) or Item Type X Condition interaction was obtained, $F(2,24) = 1.08$, $MSE = 0.92$.

Please insert table 5 about here

Recall during the additional phase (Phase 3) and confidence. The percentage of recall of the critical lures during the additional phase was computed for each participant (see table 4). A one-way ANOVA was carried out on the mean proportion of critical lures recalled during the additional phase. There was a significant main effect for Condition, $F(2,24) = 7.54$, $MSE = 0.06$. As expected, ‘longer ISI’ participants produced significantly more critical lures during the additional phase than any other condition. The probability of producing the critical lure was reduced in ‘shorter ISI’ participants.

As in experiment 1, an index was computed by dividing the number of critical lures recalled during the additional phase by the number of critical lures that could still be recalled theoretically by each participant. A one-way ANOVA was carried out on these mean indices and revealed a main effect for Condition, $F(2,45) = 3.98$, $MSE = 0.06$. The mean index in the shorter ISI condition (.59) was statistically lower than the indices in the two other conditions (.79 and .76 for the ‘standard ISI’ and ‘longer ISI’ groups, respectively).

When the mean indices were compared to the theoretical proportion of 0.5, only the mean index in the ‘standard ISI’ and ‘longer ISI’ groups were statistically higher than the theoretical proportion of 0.5 [$t(15) = 3.29$ and 3.12 for the ‘standard ISI’ and ‘longer ISI’ groups, respectively] whereas the mean index in the ‘shorter ISI’ group was not statistically different from the theoretical proportion of 0.5 [$t(15) = 1.03$]. These results suggest that some evidence of monitoring exists in each condition, but that only the ‘standard ISI’ and ‘longer ISI’ groups were above the chance level.

Finally, the proportions of critical lures recalled during the memory test plus critical lures produced during the additional phase were also computed and compared (see table 4). Condition had no significant effect on the proportion of critical lures activated, F $(2,45) = 1.45$. As in experiment 1, this finding is important, because it suggests that the participants were equally likely to think of the critical lure regardless of the length of the ISI. In accordance with the Source Monitoring Framework, manipulating the ISI during study was sufficient to affect the production of the critical lure during the additional phase, suggesting that ISI influences participants’ ability to efficiently monitor the source of activation. Finally, a one-way ANOVA was carried out on the mean confidence ratings assigned to the critical lures produced during the additional phase (see table 5) and did not reveal any effect for Condition, $F(2,44) = 1.64$.

As predicted lengthening the ISI was sufficient to increase true performance and decrease the rates of false memories. Although a different methodology was used, these results are in accordance with McDermott and Watson's (2001) findings. The use of the modified recall procedure more clearly identified the causal mechanisms of this effect. That is, manipulating ISI had no impact on the activation of the critical lures. Instead, manipulating ISI impacted participants' ability to effectively monitor the source of the activation for critical lures.

In addition, one striking result is that a longer ISI was found to be effective on its own to almost eliminate the DRM effect in this study, although DRM false memories are known to be particularly difficult to avoid (see, for example, McDermott & Roediger, 1998; Roediger et al., 1998). One explanation might be that engaging in item-specific processing allowed younger adults to reject critical lures, because the lures lacked the same level of detail that accompanied the studied items. Another explanation might be that this manipulation not only allowed for the encoding of more item-specific information, but may also have provided participants with the opportunity to tag the critical lure as not having being explicitly presented in the list (see Gallo et al., 1997).

However, two recent studies that manipulated the rates of presentation failed to obtain any effect on false recall (Watson et al., 2004) or false recognition (McCabe & Smith, 2002). One explanation might be that, in the previous studies, participants were presented with one large list consisting of several DRM lists added together whereas, in this study, the participants were presented with DRM lists in isolation. This could be a more favourable condition for encoding distinctive information with longer ISIs. That is, it would very likely be easier to edit memory performance in several small sessions in which one list of 15 items is presented than in a single session in which a long list, consisting of four sub-lists, has to be remembered. The striking reduction in instances of false recall obtained in the longer ISI condition may also be related to specificities of the lists. For instance, a recent study has shown that false memory editing is especially efficient when critical lures were easily identifiable (Neuschatz, Benoit, & Payne, 2003). In a previous pilot study, the critical lures from the lists used as the material to be remembered in the current study were identified by 100% of the participants (see Dehon & Brédart, 2004). Hence, in comparison to other studies, the longer ISI condition used here combines several very good encoding conditions: a longer ISI, separate small learning sessions, and study lists for which the critical lures were easily identifiable. This probably helped the participants to better edit their memory performance by quickly identifying the critical lure and detecting that it was not in the list.

Experiment 3

Older adults are thought to rely on indistinct information, because they are not able to engage in multiple processes at encoding (e.g., Craik, 1982). Given the significant reduction observed in younger adults with the use of a longer ISI, the aim of experiment 3 was to explore whether the use of a lengthened ISI in older adults would also improve their memory performance in terms of true recall and efficient source monitoring. To test this hypothesis, ISI was manipulated only in older adults (i.e., ‘standard ISI’ vs. ‘longer ISI’) and the performance of the participants in those conditions was compared to that of a group of young adults under standard conditions (i.e., ‘standard ISI’). It was hypothesised that, in comparison to the standard condition, a longer ISI would give older adults more time to extract more item-specific information. The increased amount of item-specific information could be used, in turn, to avoid the false recall of critical lures.

It is worth noting that some studies exist in which older adults have been observed to engage in distinctive processing of items. This distinctive processing allowed for a reduction in false memories without the need to slow down the rate of presentation. However, in these studies, the distinctive information was not generated by the participants but provided externally, for instance, in the form of a specific word or sentence (i.e., Thomas & Sommers, 2004) or a distinctive picture (i.e., Schacter, Israel, & Racine, 1999). Hence, older adults have been shown to reduce the occurrence of false memories through distinctive encoding, but only when contextual support is provided. This suggests that older adults may fail to spontaneously use strategies that could help them to avoid memory errors. However, deficits in the spontaneous use of such strategies are not restricted to encoding processes (see Dehon & Brédart, 2004; Koutstaal, 2003; Koutstaal et al., 1999; Multhaup, 1995).

For these reasons, the question of whether a failure to spontaneously engage in source monitoring processes could account for older adults' pattern of performance was also explored. In addition to the use of a longer ISI, warnings *before study* were given to a separate group of older adults (i.e., 'longer ISI + warnings') to help participants focus on the studied items. These participants were explicitly informed of the nature of the DRM illusion, and were also provided with an example of a list similar to those used in the experiment.

As in the two previous experiments, the use of the modified procedure in this study allowed for the direct assessment of the activation and monitoring of critical lures. It was predicted that, in comparison to standard circumstances, conditions that enhanced the encoding of item-specific information would improve recall of critical lures in the additional phase. However, because aging has been associated with spared activation of the critical lure (Dehon & Brédart, 2004), and because the manipulation used was not expected to affect presentation of the material to be remembered per se, no effect on activation rates was predicted for the different conditions.

Method

Participants. Twenty-four psychology students (mean age = 21.75 years) and 72 older adults (mean age = 73.57) participated in the experiment. The older adults were randomly assigned to one of three experimental conditions. Two conditions varied in terms of the ISI used during the learning phase: ‘standard old’ (ISI = 1.5 s) and ‘longer old’ (ISI = 3 s). The additional condition (‘longer + W’) was designed to test whether older adults would engage in item-specific processing, but would not spontaneously use the item-specific cues to discriminate items that were studied from items that were only imagined. In this condition, strong warnings were given prior to study and the ISI was lengthened. The ISI length used in the group of young adults (‘standard young’) was 1.5 s.

Participants were also selected according to educational background and had at least 11 years of education. The mean number of years of education (15.02 $\pm$ 3.04, 14.56 $\pm$ 1.94, 14.70 $\pm$ 2.03 and 13.99 $\pm$ 3.28 for the ‘standard young’, ‘standard old’, ‘longer old’ and ‘longer + W’ groups, respectively) was similar across the experimental conditions, $F(9,92) < 1$. However, on average the older adults exhibited significantly higher scores on the Mill Hill Vocabulary Test (37.68 $\pm$ 3.64, 37.83 $\pm$ 4.02 and 37.79 $\pm$ 4.23 for ‘standard old’, ‘longer old’ and ‘Longer + W’ groups, respectively) than the younger participants (35.33 $\pm$ 3.62), $F(3,92) = 2.79$, $MSE = 13.74$.

Materials and procedure. The recorded lists from the ‘standard ISI’ and ‘longer ISI’ conditions of experiment 2 were used as material to be remembered. The same general procedure was used in all the conditions in experiment 3 except that the ISI was only manipulated in older adults with or without the addition of strong warnings before the study phase.

Results and discussion

The descriptive data as a function of the experimental condition are presented in table 4. For all the following analyses, the alpha level was set at .05.

Please insert table 6 about here

Performance in recall (Phase 1).

The proportions of non-critical intrusions, mainly semantically related intrusions, were not statistically affected by any experimental manipulation, $F(3,92) = 1.61$, $MSE = 0.01$, $p = .18$. Because these proportions were very low ($\leq .03$ in all the conditions), they did not undergo further statistical analyses.

A 4 (Condition: ‘standard young’ vs. ‘standard old’ vs. ‘longer old’ vs. ‘longer + W’) X 2 (Item Type: ‘studied item’ vs. ‘critical lure’) ANOVA with repeated measures on the last factor was performed on the mean proportions of true and false recall (see table 6). This analysis did not reveal a main effect of the Condition, $F(3,92) = 1.08$, $MSE = 0.03$. However, a significant main effect of the Item Type was obtained, $F(1,92) = 85.50$, $MSE = 0.03$. Participants recalled more studied items (.51 $\pm$ .11) than critical lures (.25 $\pm$ .19). In addition, the Condition X Item Type interaction was also significant, $F(3,92) = 12.97$, $MSE = 0.03$. Planned contrasts showed that, in comparison to the ‘standard old’ condition, lengthening the ISI in older adults increased the proportion of studied items recalled [$F(1,92) = 4.55$, $p < .04$; $F(1,92) = 8.75$, $p < .004$ compared to the ‘longer old’ and ‘longer + W’ conditions, respectively]. However, younger adults still recalled significantly more studied items than ‘standard old’, ‘longer old’ and ‘longer + W’ adults, $F(1,92) = 35.39$, $p < .0001$; $F(1,92) = 16.72$, $p < .0001$, $F(1,92) = 10.66$, $p < .01$. As expected, compared to a standard situation (i.e., ‘standard old’ condition in this case), lengthening the ISI for older adults significantly decreased in the proportion of critical lures falsely recalled, resulting in a marginally significant difference in the ‘longer old’ condition, $F(1,92) = 2.91$, $p = .08$; but the difference became statistically significant in the ‘longer + W’ condition, $F(1,92) = 11.49$, $p = .001$. In addition, younger adults falsely recalled significantly fewer critical lures than ‘standard old’ and ‘longer old’ adults, $F(1,92) = 13.07$, $p < .001$; $F(1,92) = 3.700$, $p < .05$. However, age-related differences in false memory production disappeared with the ‘longer + W’ condition, $F < 1$. Finally, the proportion of studied items recalled was larger than the proportion of critical lures recalled in the ‘standard young’, ‘longer old’ and ‘longer + W’ conditions, $F(1,92) = 74.63$, $p < .001$; $F(1,92) = 12.92$, $p < .001$ and $F(1,92) = 36.80$, $p < .001$; but not in the ‘standard old’ adults $F < 1$.

A 4 (Condition: ‘standard young’ vs. ‘standard old’ vs. ‘longer old’ vs. ‘longer + W’) X 2 (Item Type: ‘studied item’ vs. ‘critical lure’) ANOVA with repeated measures on the last factor was performed on the confidence ratings assigned to true and false memories (see table 7). A significant Item Type effect was obtained, $F(1,66) = 19.36$, $MSE = 0.49$. Participants were significantly more confident when recalling studied items (4.77 ± 0.25) than when falsely recalling critical lures (4.1 ± 1.08). No other statistically significant effect was obtained, Fs < 1.

Please insert table 7 about here

Recall during the additional phase (Phase 3) and confidence. The proportion of critical lures recalled during the additional phase was computed for each participant (see table 6). A one-way ANOVA was carried out on those mean proportions and revealed a significant main effect for Condition, $F(3,92) = 4.40$, $MSE = 0.08$. As predicted, post hoc tests revealed ‘standard old’ participants to report significantly fewer critical lures during the additional phase than the ‘standard young’ and ‘longer +W’ participants. The rates of critical lures reported during the additional phase by the participants in the ‘longer old’ group were not statistically different from any other group.

Again, an index was computed by dividing the number of critical lures recalled in the additional phase by the number of critical lures that could still be recalled theoretically by each participant. When the mean indices were compared to the theoretical proportion of 0.5, only the mean indices for the ‘standard young’ and ‘longer + W’ groups (.78 and .76 respectively) were statistically higher than the theoretical proportion of 0.5 [$t(23) = 4.58$ and 4.20 for the ‘standard young ‘ and ‘longer + W’ groups, respectively] whereas the mean indices for the ‘standard old’ and ‘longer old’ groups were not statistically different from the theoretical proportion of 0.5 [$t(23) = 1.70$ and 1.06 for the ‘standard old’ and ‘longer old’ groups, respectively]. These results suggest that some evidence of monitoring exists in all the groups but that only the ‘standard young’ and ‘longer + W’ groups were above the chance level. In addition, the proportions of activated critical lures (critical lures recalled during the memory test + critical lures produced during the additional phase) were also compared. The effect of Condition was not statistically significant, $F\ (3,92) = 0.19$, $MSE = 0.07$. This finding is important because it suggests that the participants were equally likely to think of the critical lure in all conditions (see table 6). Finally, a one-way ANOVA carried out on the mean confidence ratings assigned to the critical lures produced during the additional phase (see table 7) did not show an effect of Condition, $F(3,77) = 1.74$, $MSE = 1.71$.

In conclusion, as expected, lengthening the ISI had a beneficial effect on true memory performance by the groups of older adults, although this manipulation did not completely eliminate the age-related differences in true recall. The results of the recall test and the additional phase showed that the longer ISI seemed to enable older adults to better resist false memories. In comparison to the standard condition (i.e., ‘standard old’), the better resistance shown by older adults took the form of a trend in the longer ISI participants. However, when warnings were provided in addition to a lengthened ISI, the decrease in the production of false recall in older adults reached significance. This suggests that some manipulations designed to improve false memory resistance in older adults might not always be effective (see also Watson et al., 2004).

One criticism that may be levelled against these results is that, because of the necessary delay between the study of a list and the start of the additional phase for that list, older adults were more likely to forget that they had noted that the critical lure had not been explicitly presented at study. Indeed, in those conditions, as the ISI increased, so did the time between the initial learning of a list and the additional phase for that list. However, such differential forgetting does not seem to have played a major role in our experiments, for several reasons. First, it would be hard to explain why the sum of critical lures produced in the recall test (phase 1) and in the additional phase did not differ for young and older adults in any condition. Second, it would be hard to explain why older adults falsely remembered a higher percentage of critical lures on the initial recall test in the standard condition if they were equally likely to note the non-occurrence of the critical lure. Third, the conditions involving longer ISIs would be those in which the delay is the greatest between the initial learning of a list and the additional phase for that list. However, in these conditions, it would be hard to explain why the sum of critical lures produced in the recall test (phase 1) and the additional phase did not differ for young and older adults, or why older adults might show evidence of improvement in false memory resistance or, finally, why warnings added to the lengthening of the ISI would still be efficient if older adults were more likely to forget having noted the non-occurrence of the critical lure.

General Discussion

A growing body of literature is interested in identifying the mechanisms that allow people to successfully edit their memory performance and avoid falling prey to false memories. Aging has been associated with higher rates of false memories in various paradigms (e.g., Koutstaal & Schacter, 2001) and with reduced source monitoring abilities (e.g., Spencer & Raz, 1995). Following the activation-monitoring account of age-related increase in DRM false memories, the present study was aimed at better understanding the age-related deficits in source monitoring (e.g., Johnson et al., 1993; Johnson & Raye, 2000). The experiments were designed to explore the influence of the availability of attentional resources and processing speed (both known to be associated with memory deficits in normal aging, e.g., Anderson & Craik, 2000) on activation and monitoring processes. To this end, Brédart's (2000) modified procedure was used to assess these processes more directly while manipulating attentional resources at study, at test or at both study and test (experiment 1) or processing speed at study (experiments 2 and 3).

Overall, the results replicated the finding that younger and older adults under standard conditions were equally likely to think of the critical lures but that older adults preferentially recalled them during the initial recall test while younger adults recalled them during the additional phase (see also Dehon & Brédart, 2004). These results support the idea that the activation of the critical lure in normal aging is relatively spared and that a source monitoring deficit in older adults is a factor responsible for the occurrence of false memories in the DRM paradigm. However, one criticism that could be levelled against this interpretation concerns the finding of age differences on the Mill Hill vocabulary test[1]. The fact that all groups of older adults in this set of experiments scored better on this vocabulary test may suggest that older adults have a larger, more detailed, lexical/semantic network that presumably would require less

[1] The author thanks the reviewers for bringing these suggestions to her attention.

stimulation to achieve a given level of activation than a network with a sparser degree of connectivity (i.e., in young adults). This suggestion may be supported by recent results showing that experts in a specific domain exhibited more false memories than novices for a material consistent with their area of expertise (Baird, 2001). In addition, the modified procedure that was used involved re-presenting items recalled in the recall phase, which may result in the repeated activation of the critical lure for a particular DRM list. This repeated activation may, in turn, make lure intrusions more likely. Therefore, the pattern of findings supposed to be due to age differences in source monitoring ability (i.e., high intrusion rates in the recall phase and low intrusion rates in the additional phase for older adults and the reverse pattern for younger adults) could be due to the fact that older and younger adults differ in the extent of lure activation in the recall phase, so that young adults generally do not reach a threshold level of activation until the additional phase. Yet, during the debriefing of the experiments, some subjects (mostly in younger adults) said that they knew the critical lure was not in the list because they had used it as a cue to remember the other items during encoding or because they had expected it to appear in the list but it never did. This would suggest that these people had in fact activated the critical lure during the study phase, which is not consistent with the above hypothesis.

Nonetheless, although previous research suggests that younger adults may be better at activation monitoring than older adults, it does not specify the causal mechanisms involved. According to the Source Monitoring Framework (e.g., Johnson et al., 1993; Johnson & Raye, 2000), several reasons may explain older adults' deficits in source monitoring efficiency. For instance, older adults' susceptibility to false memories and deficits in source monitoring efficiency might be due to age-related difficulties in accessing distinctive information during retrieval and/or in encoding information less distinctively (Schacter et al., 1997). Overall, the data suggest that older adults are more likely to rely upon relational processing during both encoding and retrieval, because they lack the attentional resources necessary to focus on both relational information (i.e., indistinct, thematic information) and item-specific information (e.g., Anderson & Craik, 2000; Craik, 1982).

In experiment 1, attentional resources were manipulated by dividing younger participants' attention at study, at test, or at both study and test. The results showed that the activation of the critical lures was not affected by any of the conditions, since all the experimental groups were equally likely to think of the critical lures. Conversely, the conditions that made item-specific information less accessible to younger adults either by disturbing the quality of encoding with the addition of a concurrent task at study and/or by the disturbing the efficient retrieval of this detailed information led to a performance similar to that of older adults with respect to false memories. These results are in agreement with previous studies examining other types of memory distortions and showing that younger adults respond similarly to older adults when a concurrent task is added at study (e.g., Jacoby et al., 1989; Jennings & Jacoby, 1993; Perez-Mata et al., 2002) or during retrieval (e.g., Jacoby et al., 1989).

However, only the conditions in which the quality of encoding was disrupted led to a pattern similar to the older adults'one (i.e., decreased true memories in addition to a higher susceptibility to false memories) although not completely equivalent since age-related differences in correct recall remained in the current study. Therefore, the influence of encoding-related factors on the resistance to false memory was investigated further in two experiments. Three ISI lengths were then manipulated in separate groups of young participants (experiment 2). The results showed that, in agreement with the predictions, the manipulation of the ISI affected the resistance to false memories. That is, as ISI increased, so did accurate performance and accurate source monitoring. In contrast, reducing the ISI led to decreased correct performance and an increased proportion of false recall.

The manipulation of the ISI performed with older adults (experiment 3) showed that lengthening the ISI in older adults led to an improvement of the quality of the encoding, as true recall performance improved with longer ISIs. However, a significant improvement in source monitoring accuracy in older adults was only found when warning instructions were also provided before the study phase. Moreover, the combination of those manipulations not only improved participants' resistance to false memories but eliminated age-related differences in successful source monitoring. These results suggest that, when given sufficient time at the study phase, older adults can encode specific attributes of items to improve true memory, but they successfully use this information only when explicitly asked to examine the origin of their memories (see also Koutstaal, 2003; Koutstaal et al., 1999; Multhaup, 1995). This is consistent with the contextual support hypothesis or, more specifically, with the hypothesis that there is a breakdown in self-initiated source monitoring processes (Johnson et al., 1993). Thus, contextual support can be used to improve resistance to false memories and eliminate age-related differences in memory accuracy. With this regard, the results of experiment 3 also support recent studies (Watson et al., 2004; see also McCabe & Smith, 2002) showing that warnings may help older adults to improve their resistance to false memory whereas multiple study-test occasions, like increased encoding time in the current study (both conditions in which older participants must self-initiate adequate source monitoring processes) were less effective.

Theoretically, the results of the current experiments are consistent with most dual-process accounts of false memories. This set of experiments was based on the activation-monitoring account of false memories, but the results may also fit with the fuzzy-trace theory (e.g., Brainerd

& Reyna, 2002; Brainerd et al., 2001). Indeed, both accounts imply that the critical lure will be likely to seem familiar to younger and older adults due to either activation or reliance on gist traces. In addition, both explanations rely on the availability of item-specific information for the successful editing of memories. As such, both theories suggest that the relationship between accurate and false memories should vary as a function of the availability of item-specific information (see McDermott & Watson, 2001; Seamon et al., 2003). That is, the relationship between accurate and false recall should be positive when the level of list learning is low and become negative when the level of list learning is very high (see Seamon et al., 2003). Several studies have shown that higher true performance can be associated with lower errors (e.g., McDermott & Watson, 2001; Seamon et al., 2003; Thomas & Sommers, 2004). Consistent with this suggestion, some conditions in this study showed that higher rates of true recall were associated with lower rates of false recall in situations in which verbatim/item-specific representations were made highly accessible (i.e., conditions involving increased study time). This enhanced availability of item-specific information increased true memory performance and allowed for better memory editing. Conversely, in conditions involving a shorter ISI or dual task at encoding or at both encoding and test, verbatim/item-specific information was made less available. Consequently, difficulties in memory editing on the basis of these representations occurred and higher rates of false recall associated with reduced true recall were observed. However, another contribution of the present study was to show that the negative association between true and false recall may not apply to all experimental manipulations. Indeed, the addition of a concurrent task at test (experiment 1) led to increased rates of false recall without reducing the rates of true recall. It is likely that, under these circumstances, given that encoding was held constant, verbatim/item-specific traces may have been stored but became less available because of the concurrent task at test. As a result, true memory may have been supported by both relational and reduced item-specific processing, but this reduced item-specific information may not have been sufficient to block the high familiarity of the critical lures.

One point of discrepancy between the two theoretical accounts (i.e., fuzzy-trace and activation-monitoring accounts) concerns the results of the additional phase used in the modified procedure. Indeed, this additional procedure was intended to detect whether participants were aware of thinking of the critical lures. Activation-monitoring theory posits that participants may consciously think of critical lures and that monitoring may occur during encoding. For instance, participants may monitor the critical lure during study and note that it was not presented in the list and/or inhibit it. In contrast, the fuzzy-trace account suggests that the activation of the critical lure at study is not a necessary condition for false memories to occur. Rather, critical lures seem familiar at retrieval because they are gist-consistent. However, our study has revealed that participants may consciously think of the critical lure and note that it was not in the list, which is not consistent with the fuzzy-trace account.

In conclusion, the main contribution of this study was to demonstrate that attentional resources and processing speed are important for both quantity and quality of the remembered information, especially during encoding. Specifically, the use of the modified procedure allowed us to assess activation and monitoring processes more directly and to identify the loci of these influences. That is, reducing the available resources in younger adults (either by adding a concurrent task at study and/or test or by reducing the time allocated to encode information) affected source monitoring accuracy but spared critical lure activation. Conversely, increasing the available resources for younger adults (i.e., providing more time to distinctively encode information) led to an improvement in resistance to false memory. In addition, attentional resources and speed of processing were found to be important contributors to age-related differences in resistance to false memory. That is, when the available resources in younger adults were reduced (i.e., by adding a concurrent task at study and/or test), a performance similar to that of older adults was observed with respect to the resistance to false memories. In contrast, when given sufficient time, older adults engaged in self-generated encoding processes to extract distinctive information about studied items. But, they only successfully used this information if contextual support was given to counteract their age-related susceptibility to false memories in this paradigm through the source monitoring processes.

Overall, the use of the modified procedure has proved useful for studying activation and monitoring more directly and identifying the loci of influence of several manipulations (e.g., Brédart, 2000; Dehon & Brédart, 2004, and the current study). However, several issues related to the additional phase should be further explored. For instance, the kind of strategy used by the participants in the additional phase (that is, whether they rely more on a direct (cued) recall approach or a generate-recognise approach)[1] has not yet been examined. As indicated above, based on the comments provided by participants during their debriefing, it seems that they tend to rely on a recall approach. That is, some people said that they knew the critical lure was not in the list because they made it into a cue during encoding so that they would later remember the other items or because they expected it to appear in the list but it did not. It would be interesting to further explore the kinds of strategies used by the participants. Similarly, future work should gain some insight into how participants know that an item was not presented by the experimenter and to determine whether these strategies and/or information might differ for young and older adults. For example, when participants recall an item during the additional phase, one might ask them to state whether they thought of this item during the study phase or during the retrieval phase and examine whether the resulting distribution of the critical lures is similar in both age groups. Further studies should be designed in order to explore these issues.

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Table 1

Participants' descriptive and demographic data (experiment 1). Standard deviations are presented in brackets.

	Experimental Condition					
	FA Young	FA Old	DAe	DAr	DAer	FAor
Age *(in years)*	20.70 (1.69)	70.60 (7.34)	20.65 (1.95)	21.40 (2.28)	20.40 (1.76)	21.69 (1.96)
Mill Hill *(out of 44)*	36.70 (3.25)	39.60 (1.93)	35.85 (3.70)	36.10 (3.53)	35.85 (2.68)	35.75 (3.55)
Education *(in years)*	14.45 (1.50) (from 12 to 17)	13.20 (1.51) (11 to 16)	14.35 (1.56) (12 to 17)	15.10 (2.23) (12 to 19)	14.30 (1.62) (12 to 17)	14.26 (1.69) (11 to 17)

FA young = young adults under full attention, FAold = Older adults under full attention, DAe= young adults under divided attention during encoding, DAr = young adults under divided attention during retrieval, DAer= young adults under divided attention during both encoding and retrieval, FAor= young adults responding orally during the memory test.

Table 2

Mean proportions of recall as a function of the Experimental Phase, the Response Type, and the experimental condition (Experiment 1). Standard deviations are presented in brackets.

Response type	**Experimental Condition**					
	FAyoung	FAold	DAe	Dar	DAer	FAor
Studied	.64 (.08)	.41 (.07)	.48 (.09)	.61 (.09)	.48 (.06)	.64 (.09)
Critical lures	.17 (.16)	.40 (.22)	.42 (.26)	.39 (.25)	.41 (.30)	.21 (.17)
Withheld word	.62 (.32)	.31 (.25)	.28 (.31)	.30 (.35)	.32 (.32)	.61 (.28)
Activation rate	*.79*	*.71*	*.70*	*.69*	*.73*	*.82*

FA young = young adults under full attention, FAold = Older adults under full attention, DAe= young adults under divided attention during encoding, DAr = young adults under divided attention during retrieval, DAer= young adults under divided attention during both encoding and retrieval, FAor= young adults responding orally during the memory test.

Table 3

Mean confidence ratings as a function of the Experimental Phase, the Response Type, and the experimental condition (Experiment 1). The related mean confidence ratings assigned to the various kinds of responses are also presented in italics. Standard deviations are presented in brackets.

Phase	**Response type**	**Experimental Condition**					
		FAyoung	FAold	DAe	Dar	DAer	FAor
Phase 1	Studied words	4.69 (0.28)	4.42 (1.14)	4.45 (0.36)	4.68 (0.31)	4.59 (0.38)	4.72 (0.27)
	Critical lures	3.17 (1.48)	3.78 (1.28)	3.83 (1.29)	3.29 (1.22)	3.89 (0.89)	3.52 (1.39)
Phase 3	Withheld words	4.28 (0.86)	4.02 (1.58)	4.15 (1.14)	3.94 (1.34)	4.29 (0.71)	4.10 (0.96)

FA young = young adults under full attention, FAold = Older adults under full attention, DAe= young adults under divided attention during encoding, DAr = young adults under divided attention during retrieval, DAer= young adults under divided attention during both encoding and retrieval, FAor= young adults responding orally during the memory test.

Table 4

Mean proportions of recall as a function of the Experimental Phase, the Response Type, and the experimental condition (Experiment 2). Standard deviations are presented in brackets.

Response type	**Experimental Condition**		
	ISI 0.5s	ISI 1.5s	ISI 3s
Studied word recall	.53 (.05)	.61 (.08)	.74 (.06)
Critical lure recall	.31 (.18)	.19 (.19)	.03 (.07)
Withheld word recall	.41 (.23)	.66 (.26)	.73 (.24)
Activation rate	*.72*	*.85*	*.76*

Table 5

Mean confidence ratings as a function of the Experimental Phase, the Response Type, and the experimental condition (Experiment 2). Standard deviations are presented in brackets.

Phase	**Response type**	**Experimental Condition**		
		ISI 0.5s	ISI 1.5s	ISI 3s
Phase 1	Studied	4.75 (0.20)	4.72 (0.28)	4.80 (0.14)
	Critical lures	3.02 (1.39)	3.72 (1.32)	3.67 (2.31)
Phase 3	Withheld words	3.91 (1.25)	4.20 (1.32)	4.55 (0.48)

Table 6

Mean proportions of recall as a function of the Experimental Phase, the Response Type, and the experimental condition (Experiment 3). The related mean confidence ratings assigned to the various kinds of responses are also presented in italics. Standard deviations are presented in brackets.

Response type	**Experimental Condition**			
	Young 1.5s	old 1.5s	Old 3s	Old 3s + W
Studied word recall	.63 (.08)	.41 (.12)	.49 (.12)	.52 (.14)
Critical lure recall	.17 (.15)	.38 (.23)	.28 (.20)	.18 (.20)
Withheld word recall	.50 (.36)	.28 (.18)	.42 (.25)	.50 (.32)
Activation rate	*.67*	*.66*	*.70*	*.68*

Note. Young 1.5s = young adults with an ISI rate of 1.5 s, old 1.5s = older adults with an ISI rate of 1.5 s, Old 3s = older adults with an ISI rate of 3s, Old 3s + W= older adults with an ISI rate of 3s in combination with warnings before the study phase.

Table 7

Mean confidence ratings as a function of the Experimental Phase, the Response Type, and the experimental condition (Experiment 3). Standard deviations are presented in brackets.

Phase	**Response type**	**Experimental Condition**			
		Young 1.5s	Old 1.5s	Old 3s	Old 3s + W
Phase 1	Studied words	4.80 (0.17)	4.69 (0.35)	4.90 (0.20)	4.72 (0.30)
	Critical lures	3.97 (1.10)	4.19 (1.22)	4.18 (1.01)	4.06 (1.01)
Phase 3	Withheld words	4.11 (1.10)	4.55 (0.81)	4.28 (1.04)	3.93 (0.92)

Note. Young 1.5s = young adults with an ISI rate of 1.5 s, old 1.5s = older adults with an ISI rate of 1.5 s, Old 3s = older adults with an ISI rate of 3s, Old 3s + W= older adults with an ISI rate of 3s in combination with warnings before the study phase.

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